CLAIMS

1. A crawler belt bushing producing method, wherein a workpiece of a crawler belt bushing made of a medium or high carbon steel or a medium or high carbon low alloy steel is heated to a quenching temperature or more; by use of a hardening system which can independently start outer circumferential surface cooling and inner circumferential surface cooling, the workpiece is first cooled from either one of its outer circumferential surface and inner circumferential surface and then cooling is carried out from the other circumferential surface so that the workpiece is hardened through its entire thickness; and then the workpiece is tempered.

2. A crawler belt bushing producing method according to claim 1, wherein said hardening system is designed to have a partition between a cooling medium for the inner circumferential surface and a cooling medium for the outer circumferential surface, taking into account the flows of the cooling media, such that the cooling media do not interfere with each other during cooling of the workpiece.

3. A crawler belt bushing producing method according to claim 1, wherein after the workpiece is substantially uniformly and entirely heated to a quenching temperature by furnace heating and/or induction heating, the workpiece is first cooled from either one of the inner circumferential surface and outer circumferential surface, and one or more seconds later, the workpiece is cooled from the other circumferential surface.

4. A crawler belt bushing producing method according to claim 1, wherein while scan induction heating in the axial direction of the

workpiece being carried out from either one of the inner circumferential surface and outer circumferential surface, cooling of the heated surface with a spray is started from either one of the inner circumferential surface and outer circumferential surface, and one or more seconds later, cooling of the heated surface with a spray is started from the other circumferential surface.

5. A crawler belt bushing producing method according to claim 1, wherein said tempering process is carried out at 140 to 300℃.

6. A crawler belt bushing producing method according to claim 1, wherein the hardness of the inner circumferential surface is adjusted to Rockwell hardness (C type) H_{RC} 45 to 55 by said tempering process.

7. A crawler belt bushing producing method according to claim 6, wherein said adjustment of the hardness of the inner circumferential surface is carried out by stopping the induction tempering from the inner circumferential surface and/or the cooling from the inner circumferential surface during quenching operation, earlier than the cooling from the outer circumferential surface, thereby allowing self-tempering of the inner circumferential surface.

8. A crawler belt bushing producing method wherein, after a workpiece of a crawler belt bushing made of steel is heated to a quenching temperature,

(a) the cooling rate of the outer circumferential surface of the workpiece is increased by first cooling of the workpiece from its inner circumferential surface in order to reduce heat capacity at the core of the

workpiece and by second cooling of the workpiece from its outer circumferential surface which is started a certain time after the first cooling and/or

(b) the cooling rate of the outer circumferential surface of the workpiece is increased by first cooling of the workpiece from its inner circumferential surface in order to partially make the core of the workpiece unhardenable by utilizing the mass effect of the wall of the workpiece and by second cooling of the workpiece from its outer circumferential surface which is started a certain time after the first cooling,

whereby a soft layer is formed within the core of the workpiece at a cross-sectional position closer to the inner circumferential surface and the hardened depth of the outer circumferential surface is made to be greater than the hardened depth of the inner circumferential surface,

said processes (a) and (b) being carried out within one cycle of quenching operation, using a hardening system capable of performing inner circumferential surface cooling and outer circumferential surface cooling.

9. A crawler belt bushing producing method according to claim 8, wherein said hardening system is designed to have a partition between a cooling medium for the inner circumferential surface and a cooling medium for the outer circumferential surface, taking into account the flows of the cooling media, such that the cooling medium for the inner circumferential surface does not interfere with the outer circumferential surface during the first cooling from the inner circumferential surface.

10. A crawler belt bushing producing method according to claim 9, wherein said cooling media are quenching oil, water, water-soluble quenching liquid or water fog and wherein said cooling from the inner circumferential surface is jet cooling which uses a spray for substantially uniformly cooling the inner circumferential surface.

11. A crawler belt bushing producing method according to claim 8, wherein after the workpiece is substantially uniformly and entirely heated to a quenching temperature by furnace heating and/or induction heating, quenching is carried out using said hardening system.

12. A crawler belt bushing producing method according to claim 8, wherein while scan induction heating in the axial direction of the workpiece being carried out from either one of the inner and outer circumferential surfaces, scan quenching is carried out by first cooling the workpiece from the inner circumferential surface and then cooling the workpiece from the outer circumferential surface, under the condition that the temperatures of the inner and outer circumferential surfaces are quenching temperatures equal to or higher than the transformation temperatures of A1, A3 and/or Acm.

13. A crawler belt bushing producing method according to claim 12, wherein said scan quenching during the induction heating is carried out such that the workpiece, an induction heating coil, an inner circumferential surface cooling nozzle and an outer circumferential surface cooling nozzle are relatively moved in the axial direction of the workpiece and the workpiece is rotated substantially about its mean axis.

14. A crawler belt bushing producing method according to claim 8 or 9, wherein cooling from the inner circumferential surface and cooling from the outer circumferential surface are carried out at substantially the same time at least within specified regions close to the upper end face and lower end face, respectively, of the workpiece, so that the upper and lower end faces are through hardened.

15. A crawler belt bushing producing method wherein the workpiece hardened by the bushing producing method set forth in claim 8 is tempered at 140℃ to 350℃.

16. A crawler belt bushing producing method according to claim 8, wherein said workpiece is made of a steel having a carbon content equal to those of medium carbon steels and/or eutectoid steels, which is 0.35 wt% or more, and having an alloy content within the range of DI values with which the workpiece is through hardened by simultaneous cooling of the inner and outer circumferential surfaces and with which the hardened depth obtained by cooling from the inner circumferential surface only is about one half the thickness of the workpiece.

17. A crawler belt bushing producing method, wherein the inner circumferential surface of the workpiece hardened by the bushing producing method set forth in claim 8 is tempered by induction tempering so as to have a surface hardness of Vickers hardness Hv 450 to 650.

18. A crawler belt bushing producing method wherein, after a workpiece of a crawler belt bushing made of steel is induction heated from its outer circumferential surface such that at least the temperature of the

inner circumferential surface of the workpiece is raised to a quenching temperature, a series of quenching operation comprising:

(a) firstly cooling the workpiece from the inner circumferential surface;

(b) cooing the workpiece from the inner circumferential surface while heating the workpiece from the outer circumferential surface; and

(c) cooling the workpiece from the outer circumferential surface,

is performed so as to form quench hardened layers which extend toward the wall core of the workpiece from the outer circumferential surface and from the inner circumferential surface respectively and form a soft, imperfectly hardened layer between said quench hardened layers.

19. A crawler belt bushing producing method wherein, while a workpiece of a crawler belt bushing made of steel being heated from its outer circumferential surface by scan induction heating in the axial direction of the workpiece, using at least two vertically aligned, induction coils,

(a) the temperature of the inner circumferential surface of the workpiece is raised to a quenching temperature equal to the transformation temperatures of A1, A3 and/or Acm or more;

(b) the workpiece is partially heated from the outer circumferential surface by the induction coils while carrying out first cooling from the inner circumferential surface; and

(c) the workpiece is then cooled from the outer circumferential surface;

whereby the inner and outer circumferential surfaces are quench hardened so as to be substantially martensitic,

said processes (a), (b) and (c) being carried out at a certain position of the workpiece.

20. A crawler belt bushing producing method according to claim 18 or 19, wherein cooling from the inner circumferential surface and cooling from the outer circumferential surface are carried out at substantially the same time at least within specified regions close to the upper end face and lower end face, respectively, of the workpiece, so that the upper and lower end faces are through hardened.

21. A crawler belt bushing producing method according to claim 18 or 19, which uses a hardening system designed to have a partition between a cooling medium for the inner circumferential surface and a cooling medium for the outer circumferential surface, taking into account the flows of the cooling media, such that the cooling medium for the inner circumferential surface does not interfere with the outer circumferential surface during the first cooling from the inner circumferential surface.

22. A crawler belt bushing producing method according to claim 19, wherein said scan quenching by induction heating is carried out such that the workpiece, an induction heating coil, an inner circumferential surface cooling nozzle and an outer circumferential surface cooling nozzle are relatively moved and the workpiece is rotated substantially about its mean axis.

23. A crawler belt bushing producing method according to claim 21, wherein said cooling media are quenching oil, water, water-soluble quenching liquid or water fog and wherein said cooling from the inner circumferential surface is jet cooling which uses a spray for substantially uniformly cooling the inner circumferential surface.

24. A crawler belt bushing producing method, wherein the workpiece hardened by the bushing producing method according to claim 18 or 19 is tempered at 140 to 350℃.

25. A crawler belt bushing wherein quench hardened layers are formed so as to extend toward its wall core from its outer circumferential surface and from its inner circumferential surface respectively and a soft, imperfectly hardened layer is formed between said quench hardened layers,

said quench hardened layers and said soft layer being formed such that the quench hardened layer of the outer circumferential surface has a depth greater than the depth of the quench hardened layer of the inner circumferential surface, by: (a) increasing the cooling rate of the outer circumferential surface by first cooling of the workpiece from its inner circumferential surface in order to reduce heat capacity at the core and by second cooling of the workpiece from its outer circumferential surface which is started a certain time after the first cooling and/or (b) increasing the cooling rate of the outer circumferential surface by first cooling of the workpiece from its inner circumferential surface in order to partially make the core unhardenable by utilizing the mass effect of the wall of the

workpiece and by second cooling of the workpiece from its outer circumferential surface which is started a certain time after the first cooling,

the structure between said quench hardened layers being composed of one or more structures selected from ferrite, pearlite, bainite and martensite which are precipitated during cooling from the quenching temperature,

said bushing being low temperature tempered.

26. A crawler belt bushing according to claim 25, wherein the hardened depth of the outer circumferential surface is not less than 1.1 times the hardened depth of the inner circumferential surface.

27. A crawler belt bushing according to claim 25 or 26, which is made of a steel having a carbon content equal to those of medium carbon steels and/or eutectoid steels, which is 0.35 wt% or more and having an alloy content within the range of DI values with which the bushing is through hardened by simultaneous cooling of the inner and outer circumferential surfaces and with which the hardened depth obtained by cooling from the inner circumferential surface only is about one half the thickness of the bushing.

28. A crawler belt bushing according to claim 25, which is tempered at high temperature such that the quench hardened layer of the inner circumferential surface has higher hardness than the quench hardened layer of the outer circumferential surface and wherein the surface hardness of the quench hardened layer of the inner circumferential surface is adjusted to Vickers hardness Hv 450 to 650.

29. A crawler belt bushing according to claim 25, which is through hardened at its upper and lower ends.

30. A crawler belt bushing having a carbon content of 0.35 to 2.0 wt%, containing at least one of the alloying elements of Mn, Si, Cr, Mo and Ni, and made by a method in which

a bushing workpiece made of steel, which is through hardened by simultaneous cooling from the outer and inner circumferential surfaces of the workpiece, is induction heated from the outer circumferential surface so as to raise at least the surface temperature of the inner circumferential surface to a quenching temperature, and thereafter, a series of quenching operation comprising:

(a) firstly cooling the workpiece from the inner circumferential surface;

(b) heating the workpiece from the outer circumferential surface while cooing the workpiece from the inner circumferential surface; and

(c) then, cooling the workpiece from the outer circumferential surface,

is performed so as to form quench hardened layers which extend toward the wall core of the workpiece from the outer circumferential surface and from the inner circumferential surface respectively and form a soft, imperfectly hardened layer between said quench hardened layers,

said soft layer between the quench hardened layers being composed of one or more structures selected from ferrite, pearlite, bainite and martensite which are precipitated during cooling from the quenching

temperature and which contain or do not contain granular cementite dispersed therein.

31. A crawler belt bushing according to claim 30, wherein the hardened depth of the outer circumferential surface is not less than 1.1 times the hardened depth of the inner circumferential surface.

32. A crawler belt bushing according to claim 30, which is tempered at 140 to 350℃ after quenching.

33. A crawler belt bushing according to claim 30, which is through hardened at its upper and lower ends.